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CCI Land Surface Temperature

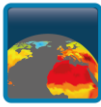
Re-gridding and Sub-setting User Manual

Ref.: LST-CCI-D3.4-3

Date: 31 August 2026

Organisation: Consortium CCI LST



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Applicable Documents

AD-1	Re-gridding and Sub-setting ATBD v0.1
AD-2	Product User Guide D4.3

1. Background

1.1. Objectives

The Re-gridding and sub-setting tool has been developed in the frame of the LST_cci project, in response to requests expressed by the users during the LST_cci Users Workshop in 2020. Its main objective is to map a LST product onto a new grid in a coarser resolution, while propagating the uncertainties in a trustable way. The tool is also able to produce a real subset of the product defined by user-provided latitude and longitude, minimum and maximum coordinates.

1.2. Scope

The tool is dedicated to LST_CCI products. It relies on input product name which must conform to the CCI naming convention. A list of currently known CCI LST products is given in table 1.

CCI LST Product Name
ERS-2_ATSR_L2P
ERS-2_ATSR_L3C
ENVISAT_ATSR_L2P
ENVISAT_ATSR_L3C
TERRA_MODIS_L2P
TERRA_MODIS_L3C
AQUA_MODIS_L2P
AQUA_MODIS_L3C
SENTINEL3A_SLSTR_L2P
SENTINEL3A_SLSTR_L3C
MSG_SEVIRI_L3U
SSMI_SSMIS_L2P
SSMI_SSMIS_L3C
MULTISENSOR_IRCDR_L3S
MULTISENSOR_IRMGP_L3S

Table 1: List of currently known LST products from [AD-2]

The tool is designed to produce an output file with a coarser resolution only. Finer resolutions are forbidden and will cause the tool to abort with an error message. Nevertheless, an output resolution equal to the input resolution is authorized.

As the tool applies a mean function on a floating window over input product, the floating window size must fit the product map: the target resolution must be a multiple of the input file resolution. (for instance, a 0.5 degrees resolution input file can be regrided toward a coarser 0.25 degrees resolution, but cannot target a resolution of 0.16 degrees: the regrided map would not fit the input one).

The tool expects variables to be present in the input file. If not, variables are simply ignored in the output file.

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Errors detected during processing are reported in a log file to help user solving it. By default, the log file is erased and kept only in case of error detection. User can avoid the log file deletion with the –keep-log option.

1.2.1. Changelog

1.2.1.1. Version 2.1

Release 2.1 adds two new climatology files for IR ASC/DESC types of products. And added logic that automatically selects the correct climatology based on the user's input products.

The tool now supports ASC/DESC infrared files.

1.2.1.2. Version 2.0

Release 2.0 focuses on adding temporal aggregation capabilities and better memory management and performance.

- ❖ Temporal aggregation: Added temporal aggregation capabilities. Users can now use the –time-resolution argument to do temporal aggregation of data over different time periods. The –time-resolution argument supports these inputs nDAILY, nWEEKLY, nMONTHLY, nYEARLY. For example, a user can input 365 days of data from January 1st to December 31st and temporally aggregate this data using the argument –time-resolution 1YEARLY (while produce one YEARLY file). The calculations are done following the ATBD equations. Similarly, a user can request MONTHLY aggregation, with –time-resolution 12MONTHLY, this will produce 12 MONTHLY files for each month.
- ❖ Memory management and performances: The tool will now consider the user's system capabilities with RAM memory and CPU cores available to make the computations as efficiently as possible. The tool should adapt to its environment automatically unless the user specifies memory and CPU cores constraints with the –memory-limit and –threads arguments. The tool has been tested on different kinds of machines with different configurations of amount of RAM and CPU cores.
- ❖ Quality of life improvements: Added multiple command line arguments to make the usage of tool easier for the user.
 - –designation (DAY, NIGHT, ASC, DES, ALL) ALL. This argument specifies which kind of files to process if the user has multiple kinds of files in the input directory. By default it will take all of them but the tool might exit if it finds incompatible files to work with.
 - –keep-tree (True, False) default False. If set to true, the same directory tree will be used in the output directory. Useful in spatial regridding.
 - –skip-existing (True, False) default False. This will skip already processed files if they are found in the output directory.
 - –skip-bad-files (True, False) default True. This will skip possibly corrupted NetCDF files in the input directory. A WARNING message will be displayed to the user if any are found.
 - –verbose : Equivalent of –log-level DEBUG.

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1.2.1.3. Version 1.2

Release 1.2 fixes two bugs reported by users. The binary interface remains unchanged.

- ❖ Fix chunk sizes: a better estimation of chunk sizes for processing tends to a better exploitation of processor on-chip RAM memory. Global performances are improved.
- ❖ Add a check on user target resolution against input file resolution

1.2.1.4. Version 1.1

The LST CCI regridding tool version 1.1 is a rehearsal of the version 1.0 with implementation of bug fixing and correction unwanted behaviour discovered during the 2022 workshop. The new implementation is related to:

- ❖ Removal of the DOI in the regridded product
- ❖ Implementation of the IR and MW use cases as defined in ATBD 1.2
- ❖ Add a verification on sub-coordinates: the sub-coordinates must be inside the input product frame
- ❖ Minor updates on error management and error display.

1.2.2. Disclaimer

The LST tool was developed with Python3 on Linux Ubuntu 20.04 and is designed to work on Linux systems. The binary file is provided for Linux and won't run on other OS.

NB: The original Python source file is not limited to Linux targets, though it has not been designed for a wider scope, nor tested on another system.

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2. Installation

The installation package is a standalone executable for Linux OS accessible to LST_cci members on the project sharepoint.

The version for the users will be made available in the Open Data Portal (tbc).

It is proposed in two versions:

- ❖ A zip file containing LST regrid tool script file and all necessary libraries (350MB Zipped - 470 MB unzipped)
- ❖ A single binary file embedding all the zipped libraries (350 MB) (requires the download of the landsea_mask folder and the two landmask files: landmask_001.nc and landmask_005.nc)

NB: The single file bundle requires the decompression of embedded libraries, consuming some overhead time before the regridding process really starts.

The LST regridding tool requires land maps (to identify cloudy pixels) and expects a directory named 'landsea_mask' containing files landmask_001.nc and landmask_005.nc beside the binary file. Those files are provided on the download page. The files are already included in the zip bundle but must be added manually beside the single self-content binary package.

2.1. Installation of the single binary file

- ❖ Download the lst-cci-regrid-v2 binary file
- ❖ Export the PATH variable in a terminal:
- ❖ *export PATH=\$PATH:/path/where/you/put/the/tool*
- ❖ Type lst_cci_regrid to run this executable file

NB: the export command can be appended to the user '.profile' file to set it automatically in each newly-opened terminal.

NB: Depending on your system setup you may have to change the permissions of your executable file. The following command will enable all users to execute the file:

```
chmod 755 lst-cci-regrid-v2
```

2.2. Installation of the zip bundle

- ❖ Download the zip file
- ❖ Decompress in a dedicated folder:
- ❖ *tar xvzf lst_cci_regrid.tgz*
- ❖ Run the lst_cci_regrid binary file: it is located at the root directory of the unpacked bundle (NB. It might be necessary to prepend './' to the binary command for the OS to recognize it: use './lst_cci_regrid')

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NB: The decompressing process takes some time to achieve the decompression of a huge number of files. Decompressed files will occupy 1.2 GB of disk space.

lst_cci_regrid tool is a binary file based on a Python3 script and can be used with the following command followed with arguments:

```
./lst-cci-regrid-v2 <arguments>
```

The 'h' option provides help on parameters:

```
lst-cci-regrid-v2 -h
```

```
usage: lst-cci-regrid [-h] [--resolution RESOLUTION] [--time-resolution TIME_RESOLUTION] [--coords
COORDS] [--output-file OUTPUT_FILE] [--threads THREADS] [--memory-limit MEMORY_LIMIT] [--
comp-level COMP_LEVEL]
                [--parallel-files PARALLEL_FILES] [--designation {DAY,NIGHT,ASC,DES,ALL}] [--keep-tree] [-
-skip-existing] [--keep-temp-files] [--keep-log] [--skip-bad-files]
                [--log-level {DEBUG,INFO,SUCCESS,WARNING,ERROR,CRITICAL}] [--verbose] [--version]
                input output_dir
```

LST CCI Regrid v2.0 - Spatial and/or temporal regridding of LST CCI products

positional arguments:

input Input LST CCI product (.nc file), directory containing products (scanned recursively),
or text file (.txt) with list of products
output_dir Output directory for processed files

options:

-h, --help show this help message and exit
--resolution RESOLUTION
 Output spatial resolution for regridding (lat lon) in decimal degrees. Use quotes if
providing both: --resolution "0.05 0.05". Single value applies to both dimensions. If not provided, only
temporal aggregation
 and/or subsetting are applied.
--time-resolution TIME_RESOLUTION
 Output time resolution for temporal aggregation. Format: [n]DAILY, [n]WEEKLY,
[n]MONTHLY, or [n]YEARLY where [n] is optional (default 1). Examples: 1MONTHLY, 5MONTHLY,
8DAILY. If not provided, only spatial
 regridding and/or subsetting are applied. When both spatial and temporal are enabled,
spatial is applied first.
--coords COORDS Rectangular spatial subsetting area: "latmin latmax lonmin lonmax". Latitudes
in [-90, 90], longitudes in [-180, 180]. Example: --coords "35 70 -10 40" for Europe
--output-file OUTPUT_FILE
 Force specific output filename (only for single file input). If not provided, filename is
auto-generated based on operations.
--threads THREADS Number of parallel CPU threads to use (default: auto = physical cores). Auto-
detected: 20 on this machine.
--memory-limit MEMORY_LIMIT

Maximum RAM memory to use during processing (e.g., 16GB, 32GB). Default: auto-detect and use 70% of available memory. Format: number followed by unit (GB or GiB).

--comp-level COMP_LEVEL

NetCDF4 compression level: 0 (none) to 9 (max), or 'auto' to match input. Default: auto

--parallel-files PARALLEL_FILES

Number of files to process in parallel during spatial regridding. Default: 1 (sequential, using all CPUs per file via Dask). Set higher for I/O-bound workloads or faster storage.

--designation {DAY,NIGHT,ASC,DES,ALL}

Filter files by designation (DAY/NIGHT for IR, ASC/DES for MW). Default: ALL (process all files)

--keep-tree Preserve input directory structure in output directory when processing recursively.

--skip-existing Skip processing if the output file already exists.

--keep-temp-files Keep intermediate/temporary files in output directory when doing combined spatial+temporal operations. Temp files are stored in <output_dir>/temp/. Default: False (temporary files are deleted after processing)

--keep-log Save a log file in the output directory with timestamped filename. Format:

lst_cci_regrid_YYYYMMDD_HHMMSS.log. Default: False

--skip-bad-files Skip unreadable/corrupt files instead of aborting. Summary of skipped files will be logged. Default: True

--log-level {DEBUG,INFO,SUCCESS,WARNING,ERROR,CRITICAL}

Set logging level (default: INFO)

--verbose Enable verbose debug logging (equivalent to --log-level DEBUG)

--version show program's version number and exit

Examples:

Temporal aggregation: daily files to monthly

lst-cci-regrid ./daily_data ./output --time-resolution 1MONTHLY

Temporal aggregation: daily files to dekadal (10-day)

lst-cci-regrid ./daily_data ./output --time-resolution 10DAILY

Spatial regridding: 0.01° to 0.25° resolution

lst-cci-regrid ./input_data ./output --resolution "0.25 0.25"

Combined: spatial regrid + temporal aggregation

lst-cci-regrid ./daily_data ./output --resolution 0.25 --time-resolution 1MONTHLY

Regional subset (Europe) with temporal aggregation

lst-cci-regrid ./input_data ./output --coords "35 70 -10 40" --time-resolution 1MONTHLY

Filter by designation (daytime IR only)

lst-cci-regrid ./input_data ./output --time-resolution 1MONTHLY --designation DAY

Control memory and parallelism

lst-cci-regrid ./input_data ./output --time-resolution 1MONTHLY --memory-limit 16GB --threads 4

Exit Codes:

0 - Success
1 - Processing error
2 - Argument parsing error
130 - Keyboard interrupt (Ctrl+C)
255 - Validation error (invalid parameters, insufficient files, etc.)

- ❖ `input_file`: input LST product is a required argument indicating the file to process.
- ❖ `Output_dir`: output directory is a required argument indicating where to store the result product.
- ❖ `h/help`: the help argument is optional and displays a quick help on tool usage
- ❖ `resolution`: the resolution argument is optional and required for regridding operations only. If not provided, only a subsetting is realised (the original image is cropped to the sub area dimensions).
- ❖ `Output-file`: the optional output-file argument is used to force the name of the output product to user's demand
- ❖ `Threads`: the optional thread argument is used to speed up the process dividing the computation into as many threads as specified. To be efficient, we advise to set a number of threads between 1 and the number of available cores on the hardware device.
- ❖ `Comp-level`: the optional compression level indicates the compression ratio into the NETCDF file. The compression-level can significantly impact the processing performances.
- ❖ `Keep-log`: the optional keep-log argument keeps the log file intact at the end of reprocessing. By default, the log file is removed if no error occurred.
- ❖ `Coords`: the optional coords argument is used to specify a sub-area. The sub-area is a rectangle aligned with latitude and longitude axis. The argument is a string composed of the 4 values separated with a space, ' ', and indicates the rectangle borders, ordered like this:
 1. latitude min
 2. latitude max
 3. longitude min
 4. longitude max

Example:

```
lst_cci_regrid <input file> <output_dir> --coords "-20 10 -100 100"
```

2.3. Output product naming

If not specified with the `--output-file` argument, the output file name is copied from the input file name with resolution field updated with the target resolution.

In other terms, in case of sub-setting without regridding, the resolution is kept: the output file name is the same as the input file name. The only way to differentiate input and output product is with the `--output-dir` argument provided in input.

NB: inside the NETCDF output product, global attributes are updated to reflect the use of the LST regridding tool.

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3. Tool data handling

3.1. Regridding and sub-setting

The LST regridding tool offers two main functions which are regridding and sub-setting.

The regridding operation lowers a product resolution according to provided parameters, with specific mean functions applied to LST variables. The regridding operation obtains a coarser resolution (it cannot output a resolution finer than the original).

The sub-setting operation is a crop step which consists in reducing tool operations to a selected sub-map defined with longitude-latitude extremum coordinates of the rectangular map under consideration. Focusing on a sub-map instead of the whole product results in a significant computation time saving.

The regridding and sub-setting operations can be used either together or separately: the mean functions are applied on the LST variables inside the sub-setting window if `--coords` is provided, or the whole product if `--coords` is not specified. By default, if no `--resolution` option is provided, only the sub-setting step is performed and the input resolution is kept.

3.2. Working steps

The tool handles a pre-defined set of variables (see AD-1) in the LST_CCI input product through a mean function before copying the result in the output product.

The output file name is computed based on the input file name and the LST_CCI file naming convention: the file resolution and creation date are replaced in the input file name.

During processing, the variable currently being processed and the mean function used are displayed.

After all variables are forwarded to the output product, the total uncertainty is computed from the actual result.

If minimum / maximum latitude and longitude coordinates are provided, the processing will be applied on this sub-map only and the output product will appear as zoomed in.

All variable attributes are preserved.

Global attributes are either copied or updated.

Input variables not identified in the predefined set are ignored.

By default, the `lst_unc_loc_atm` and `lst_unc_loc_sfc` variables mean functions is an arithmetic mean. If the output resolution is greater than 0.05 deg, then the variables mean function is `nanmean_unrelated_loc` as specified in column 2 'Propagation from 0.05°' of the following table (extracted from ATB [AD-1]).

Category	Variable		Propagation to 0.05° Daily Files	Propagation to 0.05° Monthly Files	Propagation from 0.05° (any temporal period)	(0.05° or less) Propagation within 1- month	(0.05° or less) Propagation > 1-month
Coordinates	time		Direct copy	Direct copy	Direct copy	Direct copy	Direct copy
	dtime		Eq. 1	Eq. 1	Eq. 1	Eq. 1	Eq. 1
	lat		Remapping	Remapping	Remapping	Remapping	Remapping
	lon		Remapping	Remapping	Remapping	Remapping	Remapping
	Channel		Direct copy	Direct copy	Direct copy	Direct copy	Direct copy
Geophysical variables	Lst		Eq. 1	Eq. 1	Eq. 1	Eq. 1	Eq. 1
	Lcc		Non- propagation	Non- propagation	Non-propagation	Non- propagation	Non- propagation
	lst_time_correction		Eq. 1	Eq. 1	Eq. 1	Eq. 1	Eq. 1
Uncertainty information – total uncertainty	lst_uncertainty	IR	Eq. 9	Eq. 9	Eq. 9	Eq. 9	Eq. 9
		MW	Eq. 2	Eq. 2	Eq. 2	Eq. 2	Eq. 2
Uncertainty information – individual components	lst_unc_ran		Eq. 4	Eq. 4	Eq. 4	Eq. 4	Eq. 4
	lst_unc_loc_atm		Eq. 6	Eq. 7	Eq. 7	Eq. 7	Eq. 7
	lst_unc_loc_sfc	UOL	Eq. 6	Eq. 6	Eq. 7	Eq. 6	Eq. 7
		GSW, SMW, NNEA	Eq. 6	Eq. 6	Eq. 7	Eq. 6	Eq. 7
	lst_unc_loc_cor		Eq. 6	Eq. 6	Eq. 6	Eq. 6	Eq. 6
	lst_unc_time_correction	IR	Eq. 5	Eq. 5	Eq. 5	Eq. 5	Eq. 5
		MW	Eq. 2	Eq. 2	Eq. 2	Eq. 2	Eq. 2



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Category	Variable	Propagation to 0.05° Daily Files	Propagation to 0.05° Monthly Files	Propagation from 0.05° (any temporal period)	(0.05° or less) Propagation within 1-month	(0.05° or less) Propagation > 1-month
	lst_unc_sys	Eq. 5	Eq. 5	Eq. 5	Eq. 5	Eq. 5
Retrieval information	Satze	Eq. 1	Eq. 1	Eq. 1	Eq. 1	Eq. 1
	Sataz	Eq. 1	Eq. 1	Eq. 1	Eq. 1	Eq. 1
	Solze	Eq. 1	Eq. 1	Eq. 1	Eq. 1	Eq. 1
	solaz	Eq. 1	Eq. 1	Eq. 1	Eq. 1	Eq. 1
	n	Arithmetic sum	Arithmetic sum	Arithmetic sum	Arithmetic sum	Arithmetic sum
Quality information	qual_flag	Non-propagation	Non-propagation	Non-propagation	Non-propagation	Non-propagation

Many of the CCI LST products from IR sensors are provided at a spatial resolution of 0.01° and are processed by University of Leicester (UOL). If UOL is detected in the input file, and if the input file resolution is less than 0.05°, while resolution argument is greater than 0.05 then the re-gridding is processed in two steps: to an intermediate 0.05° resolution first, then to the target resolution.

While processing, warnings and errors can occur. Both cases give rise to an informational message on the display console. The tool tries to recover from warnings but ends in error if fails. Errors provide a message and abort processing.

During the process, a log file is created as indicated in the standard output. If no error is detected, the log file is deleted. Otherwise, the log file is preserved and informs on errors (Log file can be preserved with the `-keep-log` option as argument).

4. Examples

4.1. Subsetting of a product:

```
lst_cci_regrid TDS/ESACCI-LST-L3C-LST-MODISA-0.05deg_1MONTHLY_DAY-20060701000000-fv3.00.nc output_05 --coords "0 90 0 180"
```

```
[base] [jll@b001 mpis] $ lst_cci_regrid v1.00 -i /tmp/MEI_dvtpg/charset-normalizer/assets/frequencies.json --log /tmp/MEI_dvtpg/charset-normalizer/assets/frequencies.json --output 05 --coords "0 90 0 180"
2022-09-26 10:55:54.657 INFO - log file: /tmp/MEI_dvtpg/charset-normalizer/assets/frequencies.json
2022-09-26 10:55:54.662 INFO - output 05 directory not found, creating it.
2022-09-26 10:55:54.716 INFO - spatial resolution used is geospatial lat resolution
2022-09-26 10:55:54.717 INFO - Use 8 parallel CPU threads
2022-09-26 10:55:54.718 INFO - Output file: output_05/ESACCI-LST-L3C-LST-MODISA-0.05deg_1MONTHLY_DAY-20060701000000-fv3.00.nc
2022-09-26 10:55:54.718 INFO - Input file resolution: 0.05
2022-09-26 10:55:54.718 INFO - Output file resolution: 0.05
2022-09-26 10:55:54.718 INFO - Sub grid coordinates: [0 90 0 180]
2022-09-26 10:55:54.718 INFO - .....
2022-09-26 10:55:56.023 INFO - COPY 'dtime' variable
2022-09-26 10:55:56.024 INFO - COPY 'satize' variable
2022-09-26 10:55:56.026 INFO - COPY 'sataz' variable
2022-09-26 10:55:56.028 INFO - COPY 'solaz' variable
2022-09-26 10:55:56.030 INFO - COPY 'solaz' variable
2022-09-26 10:55:56.032 INFO - COPY 'lst' variable
2022-09-26 10:55:56.034 INFO - COPY 'lst_uncertainty' variable
2022-09-26 10:55:56.036 INFO - COPY 'lst_unc_ran' variable
2022-09-26 10:55:56.039 INFO - COPY 'lst_unc_loc_ata' variable
2022-09-26 10:55:56.041 INFO - COPY 'lst_unc_loc_sfc' variable
2022-09-26 10:55:56.043 INFO - COPY 'lst_unc_sys' variable
2022-09-26 10:55:56.046 INFO - COPY coordinates 'channel'
2022-09-26 10:55:56.061 INFO - .....
2022-09-26 10:55:56.061 INFO - Writing output file
2022-09-26 10:55:56.061 INFO - File output_05/ESACCI-LST-L3C-LST-MODISA-0.05deg_1MONTHLY_DAY-20060701000000-fv3.00.nc written
2022-09-26 10:56:04.895 INFO - Regridding successfully ended.
2022-09-26 10:56:04.896 INFO - Regridding duration: 0:00:10.241478
2022-09-26 10:56:04.898 INFO - .....
```

Figure 1: console execution

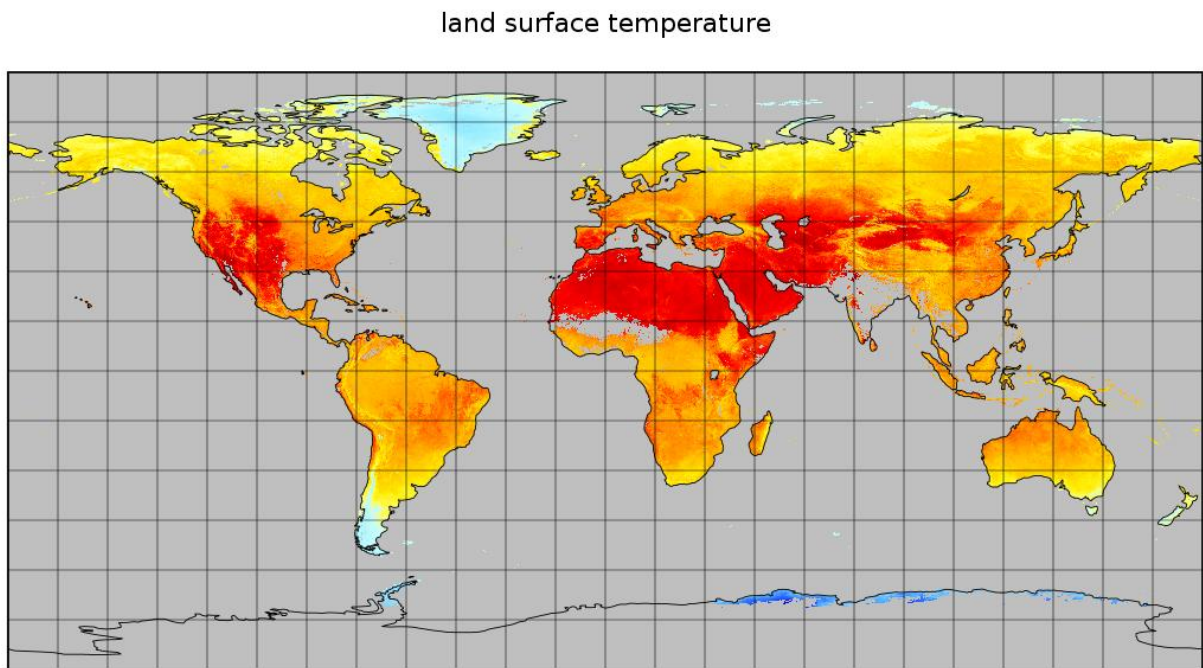
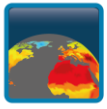


Figure 2: Original temperature



land surface temperature

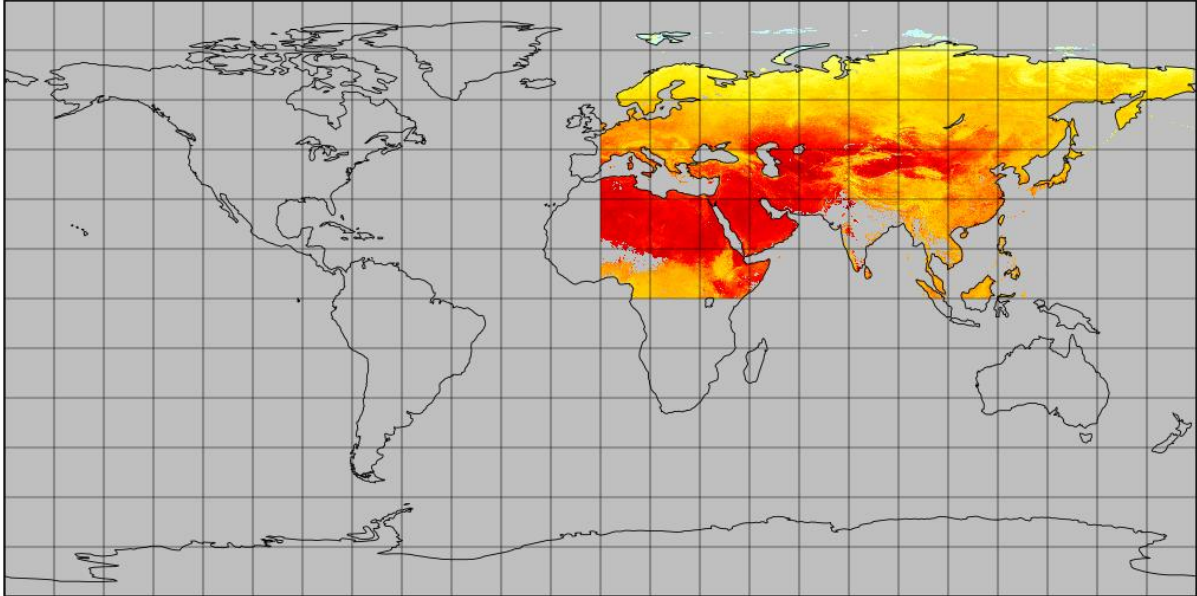


Figure 3: Sub-setted temperature

land surface temperature total uncertainty

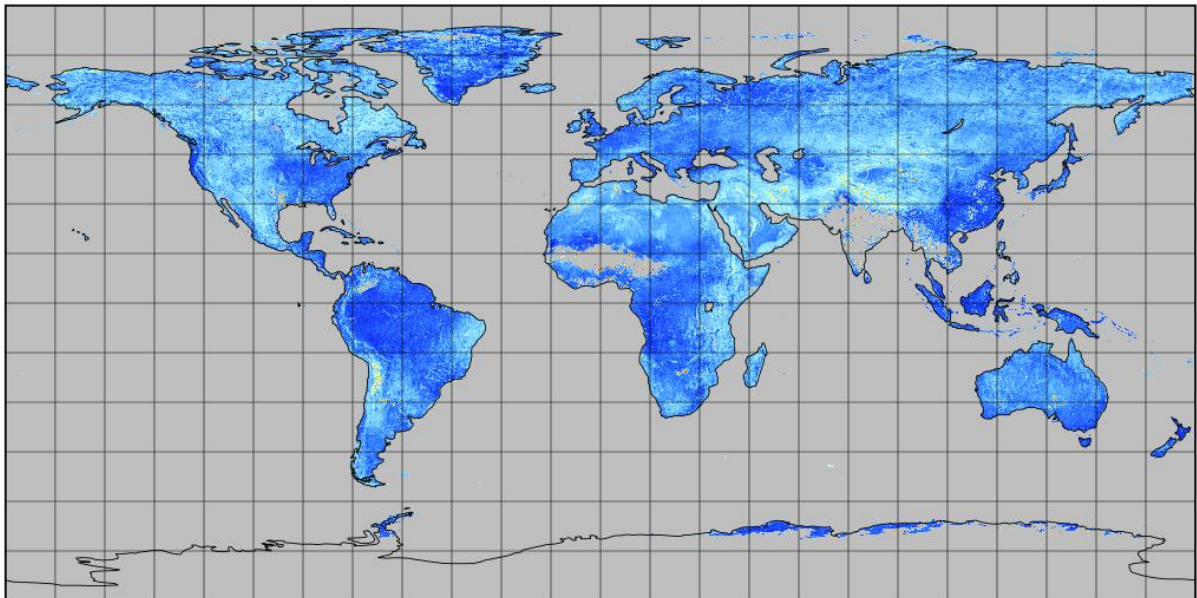
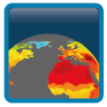


Figure 4: Original LST uncertainties



land surface temperature total uncertainty

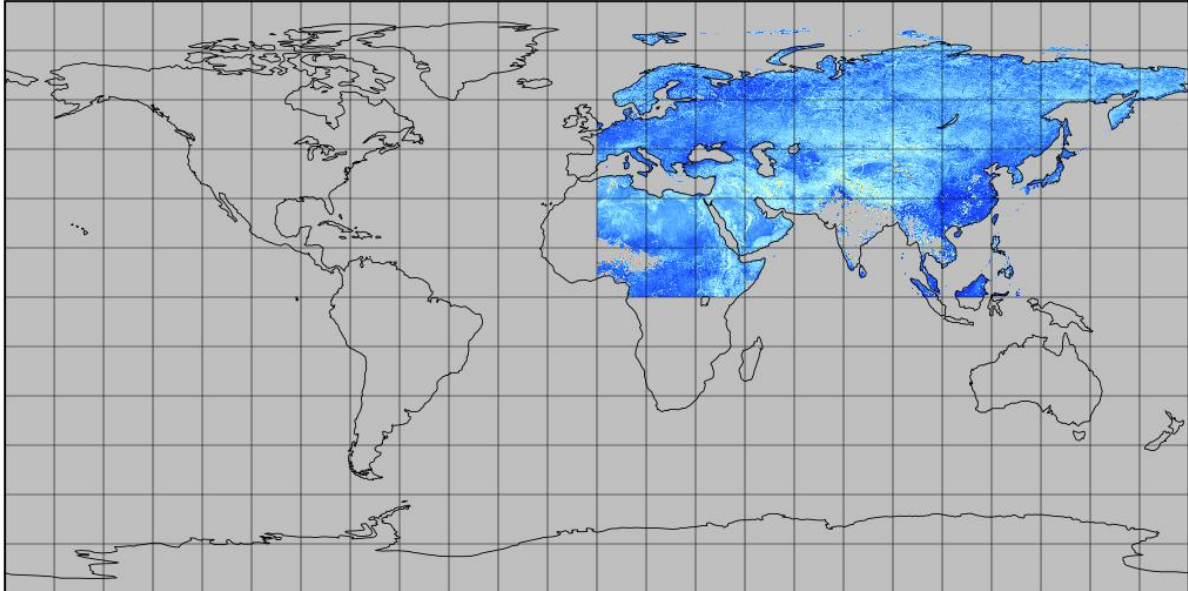


Figure 5: subset of LST uncertainties

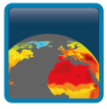
4.2. Running the regrid tool on a whole file, lowering the resolution from 0.05 degree to 0.25 degree:

```
lst_cci_regrid TDS/ESACCI-LST-L3C-LST-MODISA-0.05deg_1MONTHLY_DAY-20060701000000-fv3.00.nc output_025 --resolution 0.25
```

```
(base) [hillel@psi ~]$ lst_cci_regrid v1.00 --(lst_regrid tool/TDS/ESACCI-LST-L3C-LST-MODISA-0.05deg_1MONTHLY_DAY-20060701000000-fv3.00.nc output_25 --resolution 0.25
charset normalizer/assets/ init - py:17: UserWarning: Charset normalizer require '/tmp/ME1297np2/charset normalizer/assets/frequencies.json' to be existent for language/coherence detection. Detection WILL be weaker.
2022-09-26 11:06:54.102 INFO - log file: /tmp/ME1297np2/lst_cci_regrid ESACCI-LST-L3C-LST-MODISA-0.05deg_1MONTHLY_DAY-20060701000000-fv3.00.nc to 0.25.log
2022-09-26 11:06:54.134 INFO - output_25 directory not found, creating it.
2022-09-26 11:06:54.150 INFO - spatial resolution used is geospatial lat_resolution
2022-09-26 11:06:54.170 INFO - open 0.05 degree resolution land mask
2022-09-26 11:06:54.181 INFO - Use 8 parallel CPU threads
2022-09-26 11:06:54.181 INFO - Output file: output_25/ESACCI-LST-L3C-LST-MODISA-0.25deg_1MONTHLY_DAY-20060701000000-fv3.00.nc
2022-09-26 11:06:54.181 INFO - Input file resolution: 0.05
2022-09-26 11:06:54.181 INFO - Output file resolution: 0.25
2022-09-26 11:06:54.181 INFO - -----
2022-09-26 11:06:55.194 INFO - REGRID 'dtime' Method mean
2022-09-26 11:06:55.126 INFO - REGRID 'sataz' Method mean
2022-09-26 11:06:55.241 INFO - REGRID 'solze' Method mean
2022-09-26 11:06:55.255 INFO - REGRID 'solze' Method mean
2022-09-26 11:06:55.269 INFO - REGRID 'solze' Method mean
2022-09-26 11:06:55.284 INFO - REGRID 'lst' Method mean
2022-09-26 11:06:55.297 INFO - REGRID 'lst uncertainty' Method mean
2022-09-26 11:06:55.494 INFO - REGRID 'lst unc ran' Method nanmean uncorrelated unc
2022-09-26 11:07:00.749 INFO - lst unc loc atm: Output resolution > 0.05: use 'Propagation from 0.05 degree' algorithms
2022-09-26 11:07:00.750 INFO - REGRID 'lst unc loc atm' Method nanmean uncorrelated loc
2022-09-26 11:07:00.789 INFO - lst unc loc sfc: Output resolution > 0.05: use 'Propagation from 0.05 degree' algorithms
2022-09-26 11:07:00.789 INFO - REGRID 'lst unc loc sfc' Method nanmean uncorrelated loc
2022-09-26 11:07:00.844 INFO - REGRID 'lst unc sgs' Method nanmean fullcorr_large_scale unc
2022-09-26 11:07:14.596 INFO - COPY coordinates 'channel'
2022-09-26 11:07:14.597 INFO - Computing total uncertainties
2022-09-26 11:07:14.612 INFO - Compute sum of uncertainties
2022-09-26 11:07:19.324 INFO - -----
2022-09-26 11:07:19.325 INFO - Writing output file
2022-09-26 11:07:50.608 INFO - File output_25/ESACCI-LST-L3C-LST-MODISA-0.25deg_1MONTHLY_DAY-20060701000000-fv3.00.nc written
2022-09-26 11:07:50.664 INFO - Re-gridding successfully ended.
2022-09-26 11:07:50.664 INFO - Re-gridding duration: 0:00:56.564817
2022-09-26 11:07:50.664 INFO - -----
```

Figure 6: Example of console execution on a whole file

Display example result:



uncertainty from uncorrelated errors

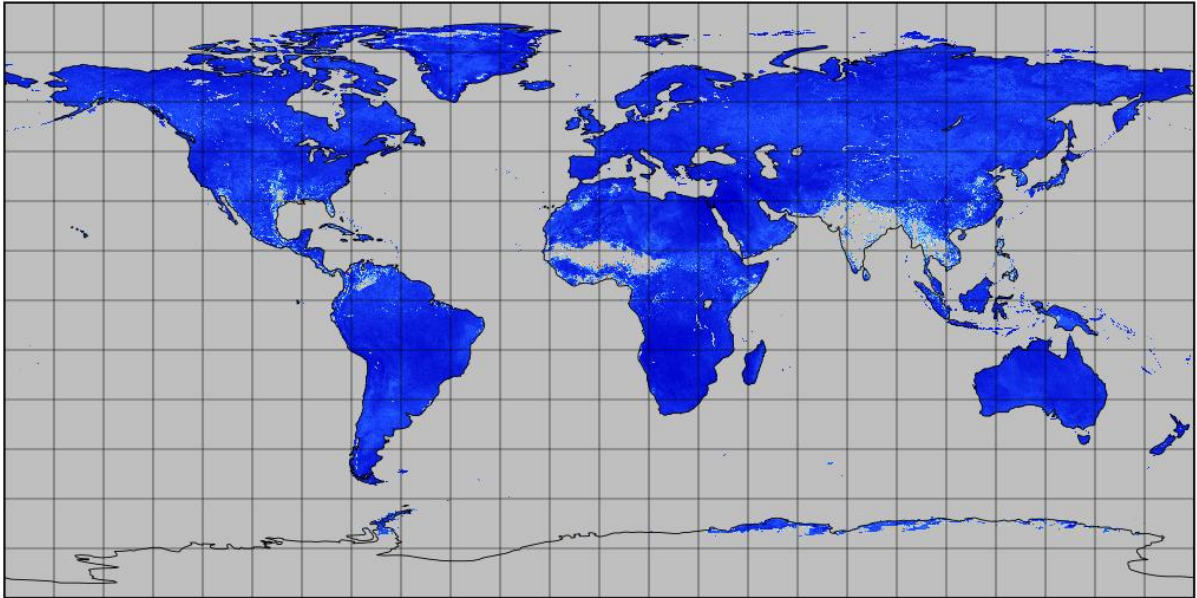


Figure 7: original *lst_unc_ran* variable

uncertainty from uncorrelated errors

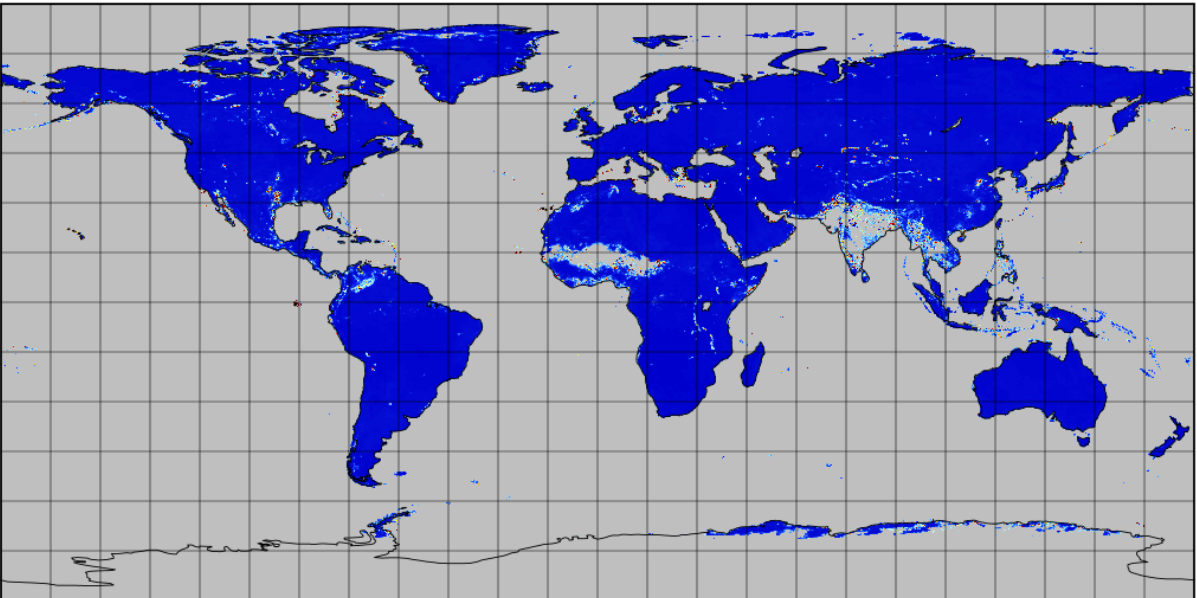


Figure 8: Regrided *lst_unc_ran* variable

uncertainty from locally correlated errors on atmospheric scales

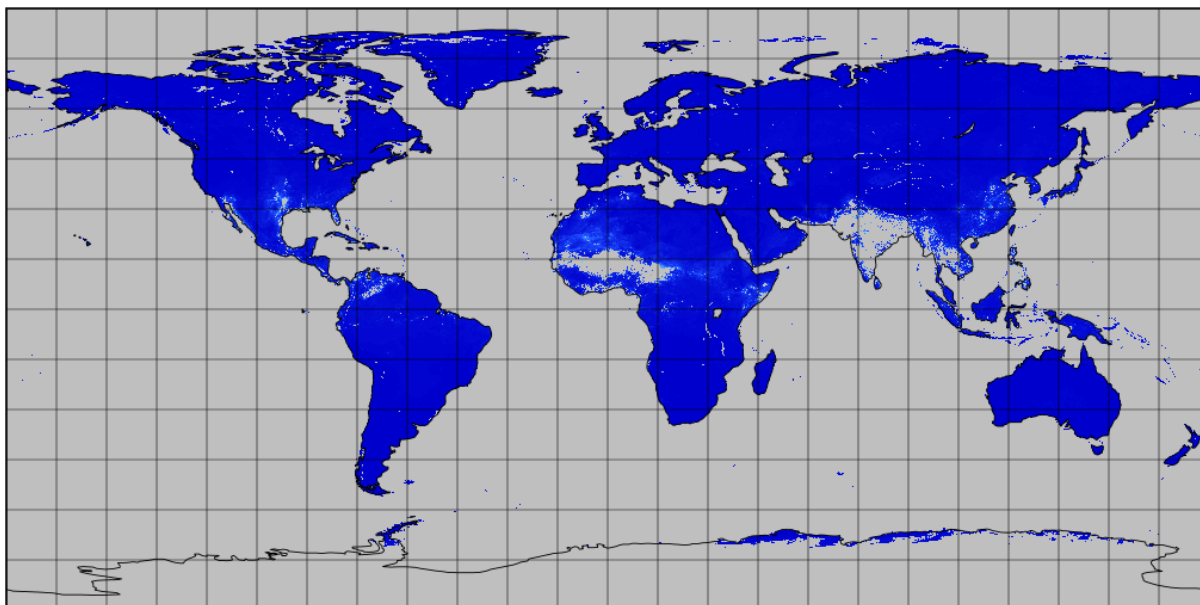


Figure 9: original file `lst_unc_loc_atm` variable

uncertainty from locally correlated errors on atmospheric scales

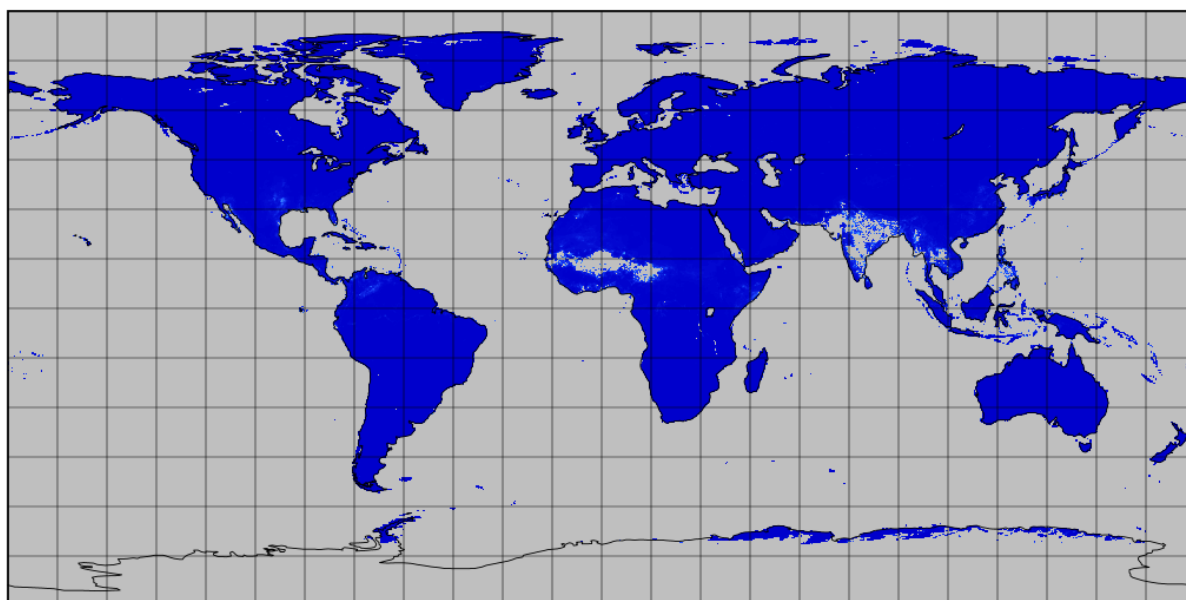
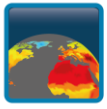


Figure 10: regridded `lst_unc_loc_atm` variable



land surface temperature total uncertainty

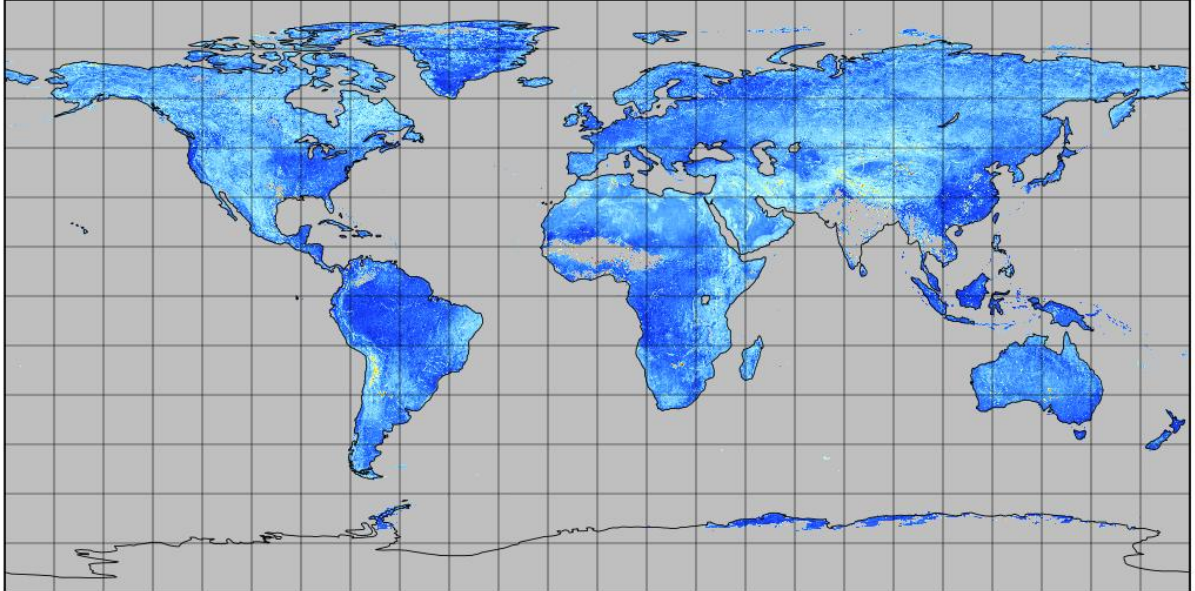


Figure 11: original file total uncertainties

land surface temperature total uncertainty

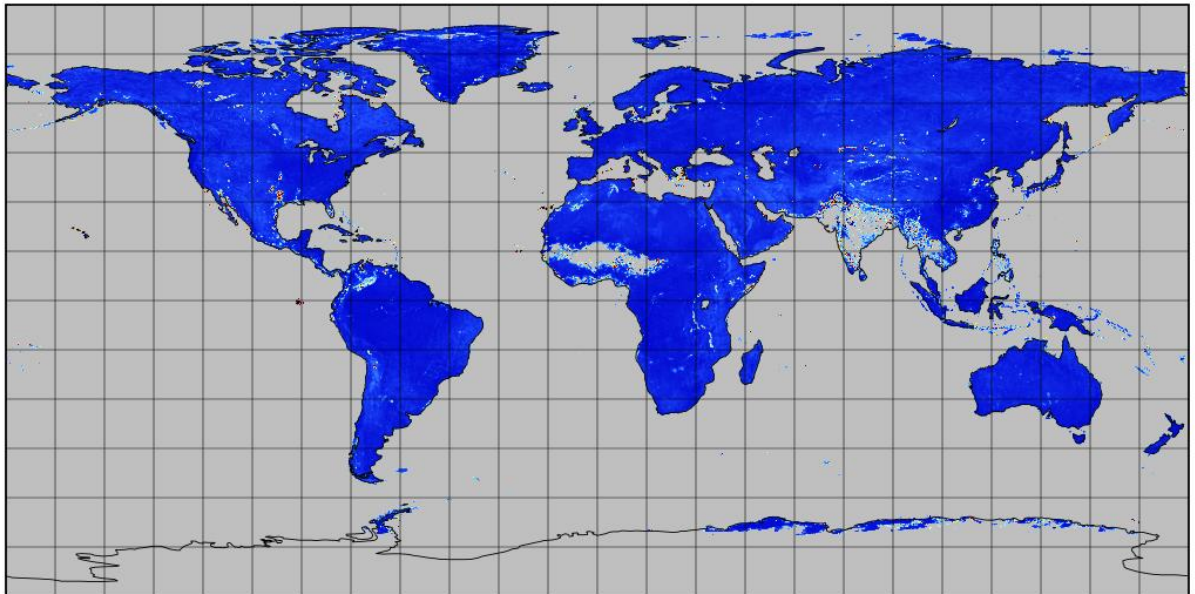


Figure 12: Regrided file total uncertainties

4.3. Running the regrid tool on a sub-area, lowering the resolution from 0.05 degree to 0.25 degree:

```
lst_cci_regrid TDS/ESACCI-LST-L3C-LST-MODISA-0.05deg_1MONTHLY_DAY-20060701000000-fv3.00.nc output_25 --coords "0 90 0 180" --resolution 0.25
```

```
(base) [hillebrand@mpi] $ lst_cci_regrid v1.00 -/tmp/MEIChyTBN/charset-normalizer/assets/frequencies.json' to be existent for language/coherence detection. Detection WILL be weaker.
2022-09-26 11:10:39,182 - INFO - log file: /tmp/MEIChyTBN/charset-normalizer/assets/frequencies.json' to be existent for language/coherence detection. Detection WILL be weaker.
2022-09-26 11:10:39,244 - INFO - spatial resolution used is geographical lat_resolution
2022-09-26 11:10:39,251 - INFO - open 0.05 degree resolution land mask
2022-09-26 11:10:39,261 - INFO - use a sub selection of land map
2022-09-26 11:10:39,264 - INFO - use 8 parallel CPU threads
2022-09-26 11:10:39,264 - WARNING - Output file output_25/ESACCI-LST-L3C-LST-MODISA-0.25deg_1MONTHLY_DAY-20060701000000-fv3.00.nc exists and will be replaced.
2022-09-26 11:10:39,265 - INFO - Input file resolution: 0.05
2022-09-26 11:10:39,266 - INFO - Output file resolution: 0.25
2022-09-26 11:10:39,266 - INFO - Sub grid coordinates: [0 90 0 180]
2022-09-26 11:10:39,266 - INFO - .....
2022-09-26 11:10:40,321 - INFO - REGRID 'dtm' Method mean
2022-09-26 11:10:40,343 - INFO - REGRID 'satze' Method mean
2022-09-26 11:10:40,351 - INFO - REGRID 'satze' Method mean
2022-09-26 11:10:40,358 - INFO - REGRID 'solze' Method mean
2022-09-26 11:10:40,366 - INFO - REGRID 'solze' Method mean
2022-09-26 11:10:40,374 - INFO - REGRID 'lst' Method mean
2022-09-26 11:10:40,382 - INFO - REGRID 'lst uncertainty' Method mean
2022-09-26 11:10:40,451 - INFO - REGRID 'lst unc ran' Method nanmean uncorrelated unc
2022-09-26 11:10:43,451 - INFO - - lst unc loc atm: Output resolution > 0.05: use 'Propagation from 0.05 degree' algorithms
2022-09-26 11:10:43,451 - INFO - - lst unc loc sfc: Output resolution > 0.05: use 'Propagation from 0.05 degree' algorithms
2022-09-26 11:10:43,473 - INFO - REGRID 'lst unc loc sfc' Method nanmean uncorrelated loc
2022-09-26 11:10:43,517 - INFO - REGRID 'lst unc sys' Method nanmean fullcorr_large scale unc
2022-09-26 11:10:45,299 - INFO - COV coordinates 'Channel'
2022-09-26 11:10:45,681 - INFO - Computing total uncertainties
2022-09-26 11:10:45,610 - INFO - Compute sum of uncertainties
2022-09-26 11:10:46,943 - INFO - .....
2022-09-26 11:10:46,943 - INFO - Writing output file
2022-09-26 11:10:55,189 - INFO - File output_25/ESACCI-LST-L3C-LST-MODISA-0.25deg_1MONTHLY_DAY-20060701000000-fv3.00.nc written
2022-09-26 11:10:55,215 - INFO - Regridding successfully ended.
2022-09-26 11:10:55,216 - INFO - Regridding duration: 0:00:16.036366
2022-09-26 11:10:55,216 - INFO - .....
```

Figure 13: Example of console execution on a sub-area

uncertainty from locally correlated errors on surface scales

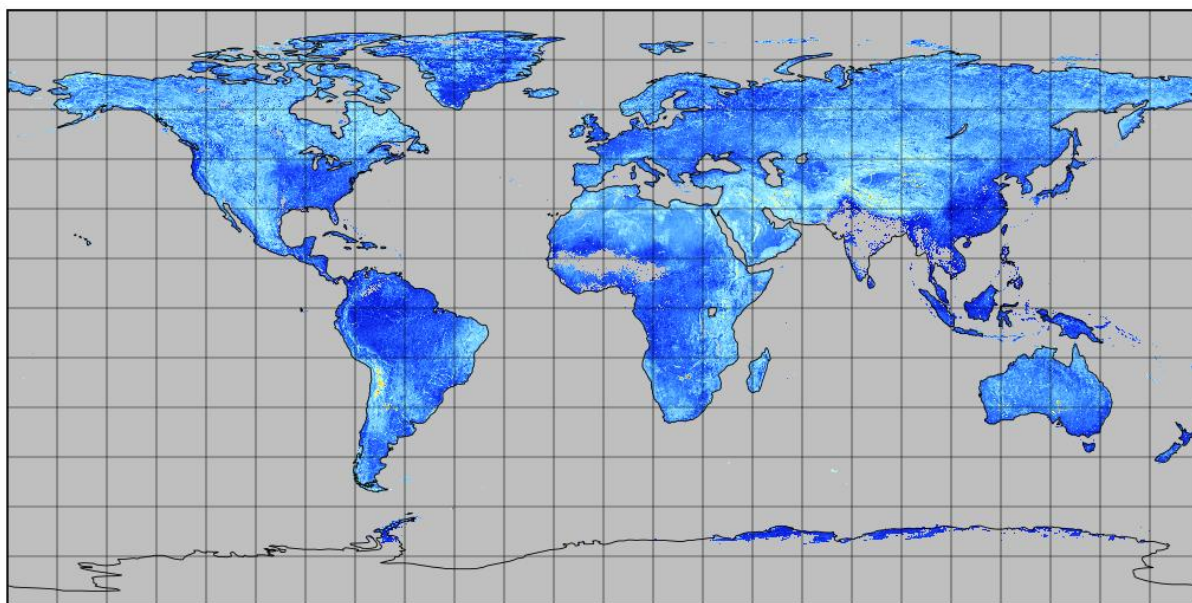
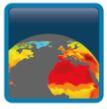


Figure 14: Original `lst_unc_loc_sfc` values



uncertainty from locally correlated errors on surface scales

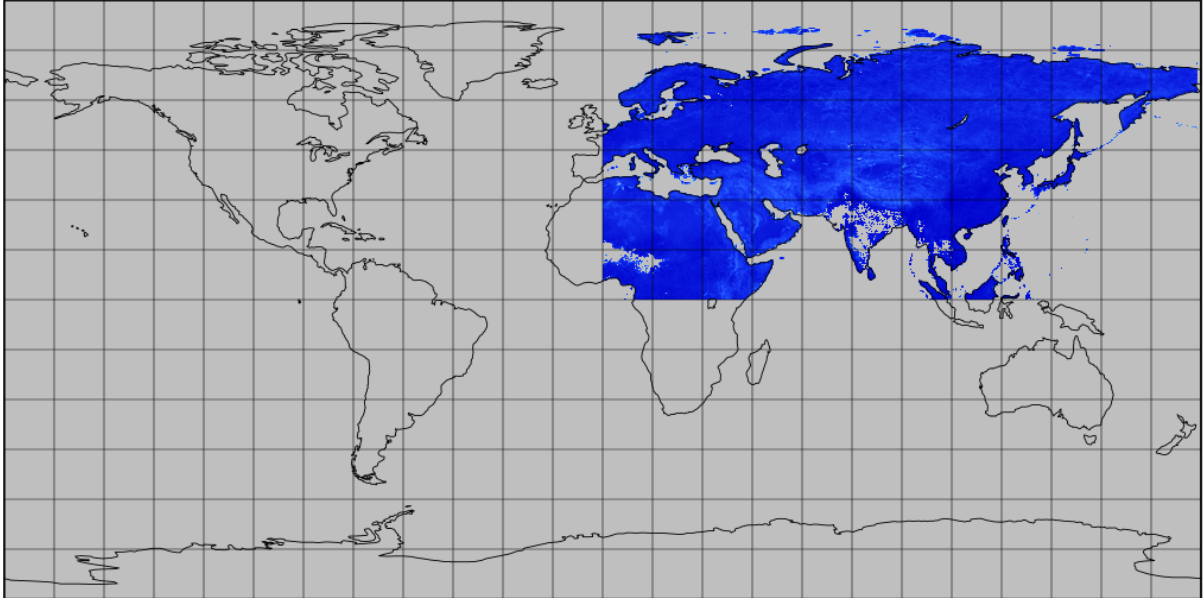


Figure 15: Regridded *lst_unc_loc_sfc* values

satellite azimuth angle

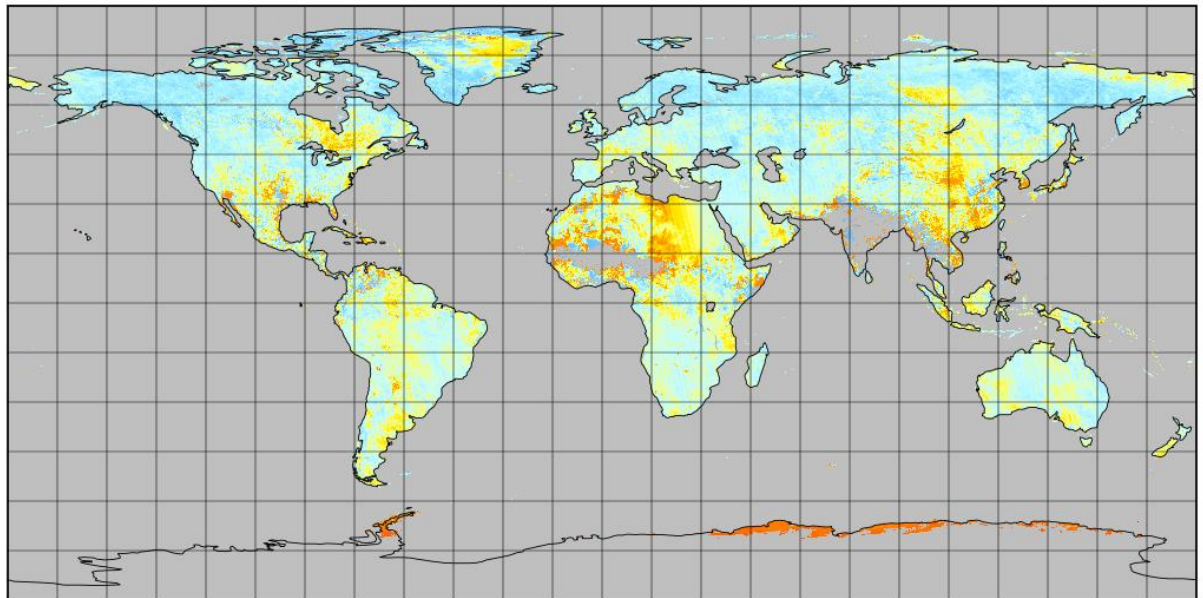
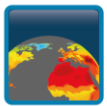


Figure 16: Original *SATAZ* values



satellite azimuth angle

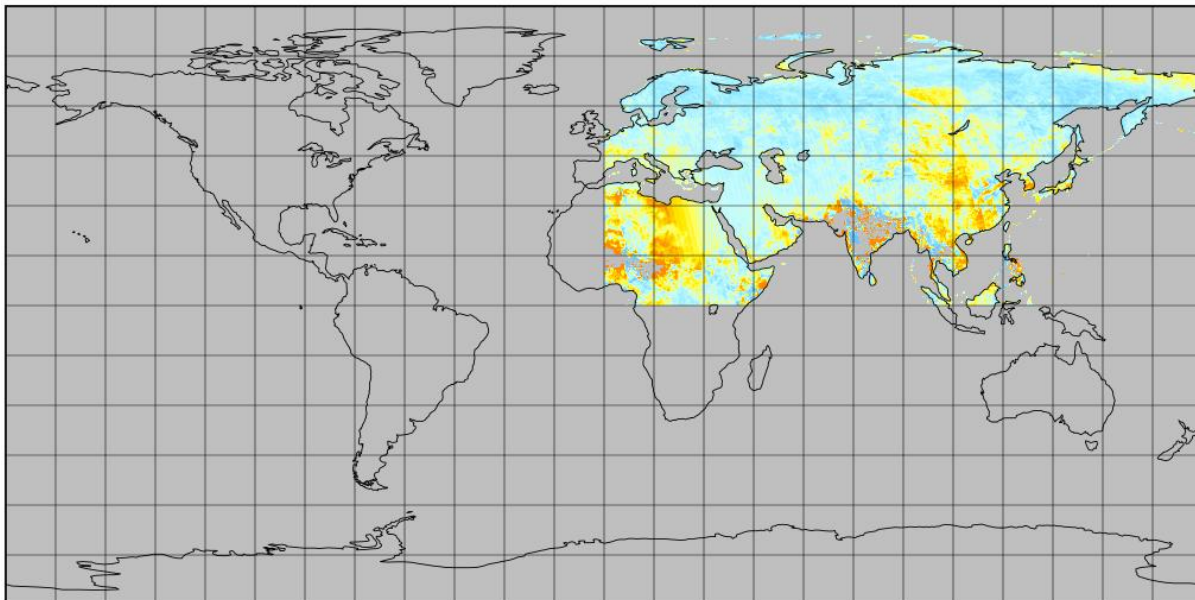


Figure 17: Regrided SATAZ values

land surface temperature total uncertainty

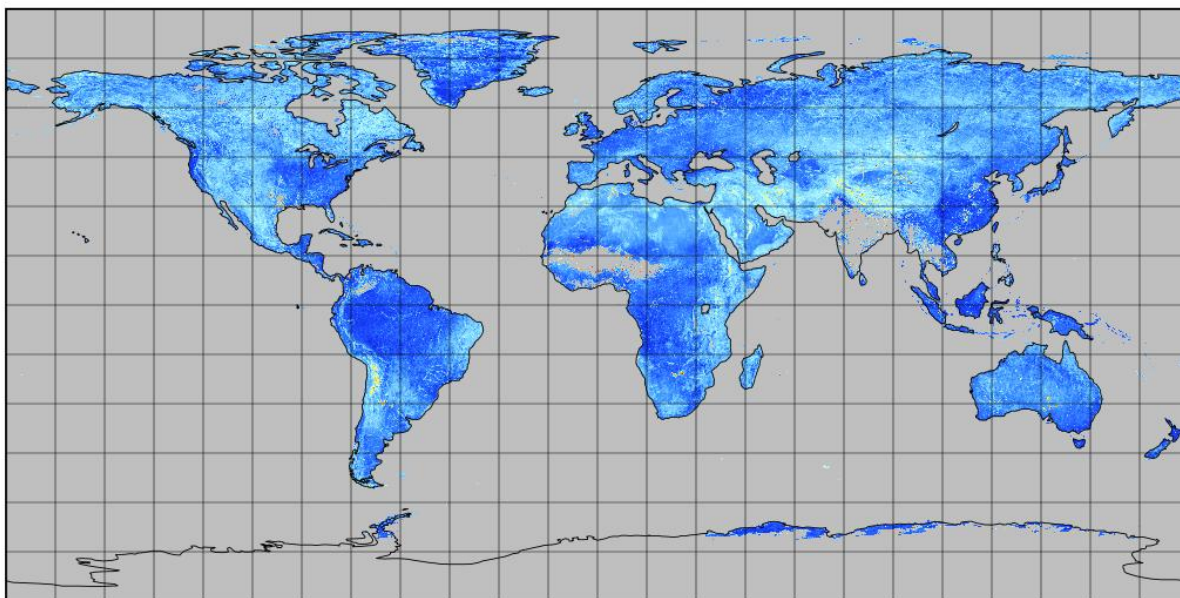
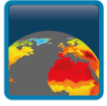


Figure 18: Original LST uncertainty



land surface temperature total uncertainty

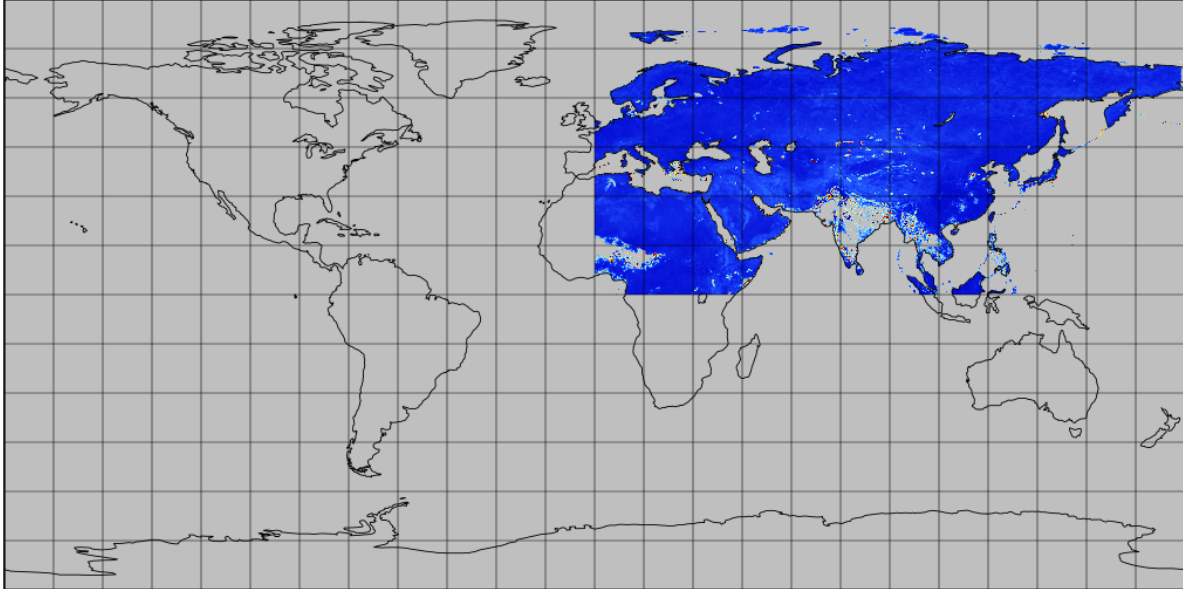


Figure 19: Regrided LST uncertainty

4.4. Running the regrid tool using '2 steps' algorithm with UOL product and threads:

```
lst_cci_regrid TDS/ESACCI-LST-L3C-LST-MODISA-0.01deg_1MONTHLY_DAY-20060701000000-fv3.00.nc output_05 --coords "0 90 0 180" --resolution 0.5 --threads 3
```

```
(base) [nath@ccil dist swefile]$ ./conda env/conda launch dist swefile/lst_cci_regrid v1.00 /lst_regrid_tool/TDS/ESACCI-LST-L3C-LST-MODISA-0.01deg_1MONTHLY_DAY-20060701000000-fv3.00.nc output_05 --coords "0 90 0 180" --resolution 0.5
2022-09-26 13:05:30.727 INFO log file: /tmp/MEiX2R0H/lst_cci_regrid/ESACCI-LST-L3C-LST-MODISA-0.01deg_1MONTHLY_DAY-20060701000000-fv3.00.nc to 0.5.log
2022-09-26 13:05:30.305 INFO output_05 directory not found, creating it.
2022-09-26 13:05:30.346 INFO spatial resolution used is geospatial lat resolution
2022-09-26 13:05:30.346 INFO 'lcc' variable found in input file;
2022-09-26 13:05:30.367 INFO Use 8 parallel CPU threads
2022-09-26 13:05:30.369 INFO Output file: output_05/ESACCI-LST-L3C-LST-MODISA-0.5deg_1MONTHLY_DAY-20060701000000-fv3.00.nc
2022-09-26 13:05:30.369 INFO 2 steps regridding:
2022-09-26 13:05:30.369 INFO Step 1: regrid to a 0.05 grid
2022-09-26 13:05:30.369 INFO Input file resolution: 0.01
2022-09-26 13:05:30.369 INFO Output file resolution: 0.5
2022-09-26 13:05:30.369 INFO Sub grid coordinates: [0 90 0 180]
2022-09-26 13:05:30.369 INFO -----
2022-09-26 13:05:55.430 INFO REGRID 'dtime' Method mean
2022-09-26 13:05:55.434 INFO REGRID 'sataz' Method mean
2022-09-26 13:05:55.463 INFO REGRID 'sataz' Method mean
2022-09-26 13:05:55.472 INFO REGRID 'solze' Method mean
2022-09-26 13:05:55.480 INFO REGRID 'solaz' Method mean
2022-09-26 13:05:55.489 INFO REGRID 'lst' Method mean
2022-09-26 13:05:55.497 INFO REGRID 'lst uncertainty' Method mean
2022-09-26 13:05:55.519 INFO REGRID 'lst_unc_ran' Method nanmean uncorrelated unc
2022-09-26 13:06:16.110 INFO lst_unc_loc_sfc: Monthly file: change lst_unc_loc_sfc function to nanmean_uncorrelated_loc
2022-09-26 13:06:16.170 INFO REGRID 'lst_unc_loc_sfc' Method nanmean loc sys unc
2022-09-26 13:06:16.221 INFO REGRID 'lst_unc_sfc' Method nanmean loc sys unc
2022-09-26 13:06:22.271 INFO IGNORE 'lcc' variable
2022-09-26 13:06:22.271 INFO REGRID 'n' Method sum
2022-09-26 13:06:22.283 INFO IGNORE 'variance' variable
2022-09-26 13:06:22.284 INFO Copy coordinates (channel)
2022-09-26 13:06:22.285 INFO Computing total uncertainties
2022-09-26 13:06:22.418 INFO Compute sum of uncertainties
2022-09-26 13:06:22.418 INFO -----
2022-09-26 13:06:28.178 INFO Step 2: regrid to target grid
2022-09-26 13:06:28.200 INFO REGRID 'dtime' Method mean
2022-09-26 13:06:28.221 INFO REGRID 'sataz' Method mean
2022-09-26 13:06:28.229 INFO REGRID 'sataz' Method mean
2022-09-26 13:06:28.237 INFO REGRID 'solze' Method mean
2022-09-26 13:06:28.245 INFO REGRID 'solaz' Method mean
2022-09-26 13:06:28.253 INFO REGRID 'lst' Method mean
2022-09-26 13:06:28.261 INFO REGRID 'lst uncertainty' Method mean
2022-09-26 13:06:28.360 INFO REGRID 'lst_unc_ran' Method nanmean uncorrelated unc
2022-09-26 13:06:34.813 INFO lst_unc_loc_sfc: Output resolution > 0.05: use 'Propagation from 0.05 degree' algorithms
2022-09-26 13:06:34.814 INFO REGRID 'lst_unc_loc_sfc' Method nanmean uncorrelated loc
2022-09-26 13:06:34.836 INFO lst_unc_loc_sfc: Output resolution > 0.05: use 'Propagation from 0.05 degree' algorithms
2022-09-26 13:06:34.836 INFO REGRID 'lst_unc_loc_sfc' Method nanmean uncorrelated loc
```

Figure 20: Example of console execution using 2 steps algorithm

uncertainty from locally correlated errors on atmospheric scales

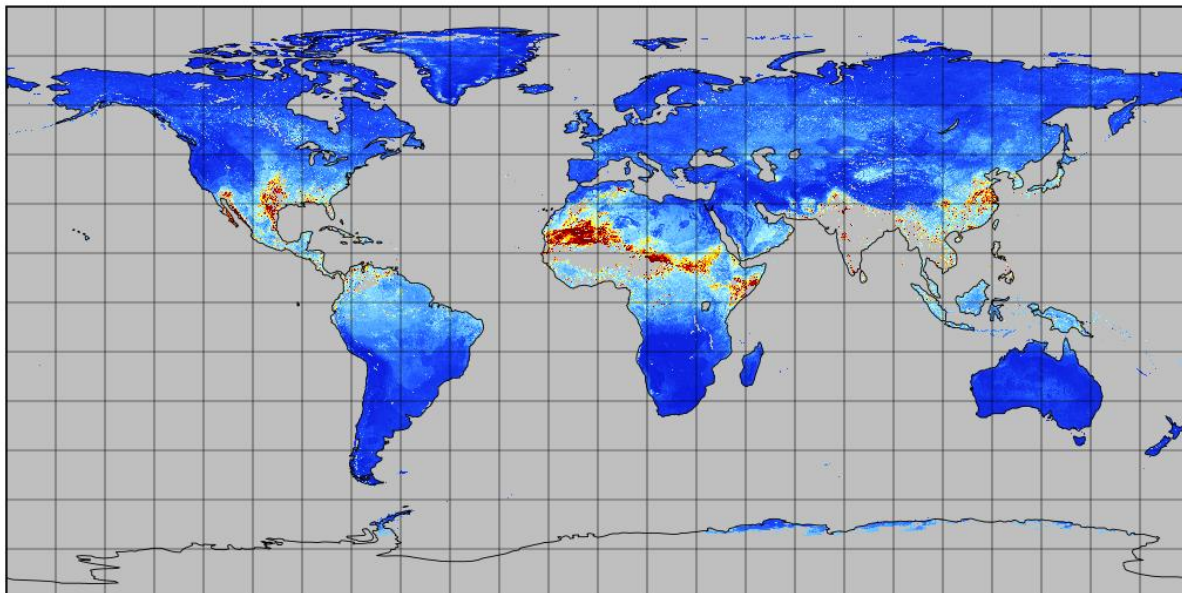


Figure 21: original file *lst_unc_loc_atm* variable

uncertainty from locally correlated errors on atmospheric scales

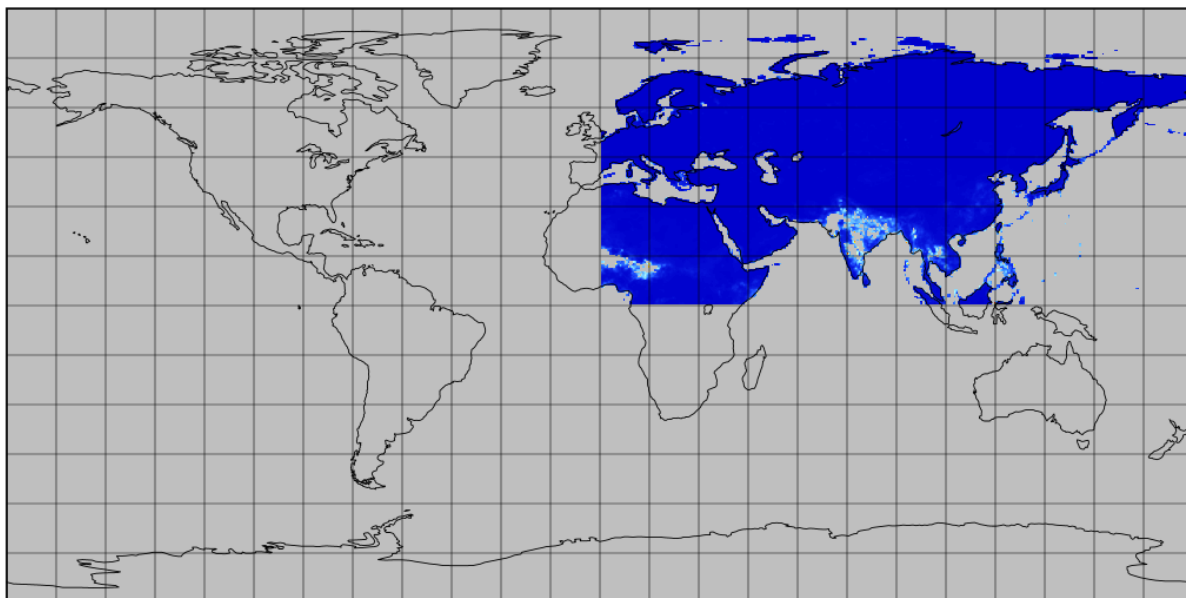
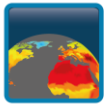


Figure 22: regridded *lst_unc_loc_atm* variable



solar azimuth angle

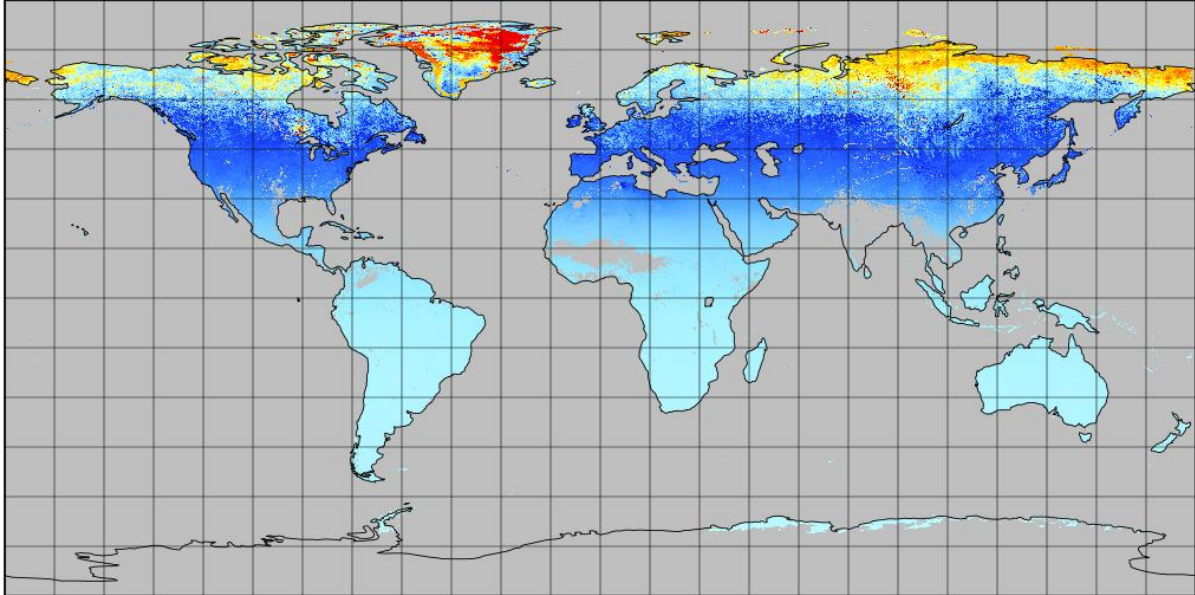


Figure 23: original solaz variable

solar azimuth angle

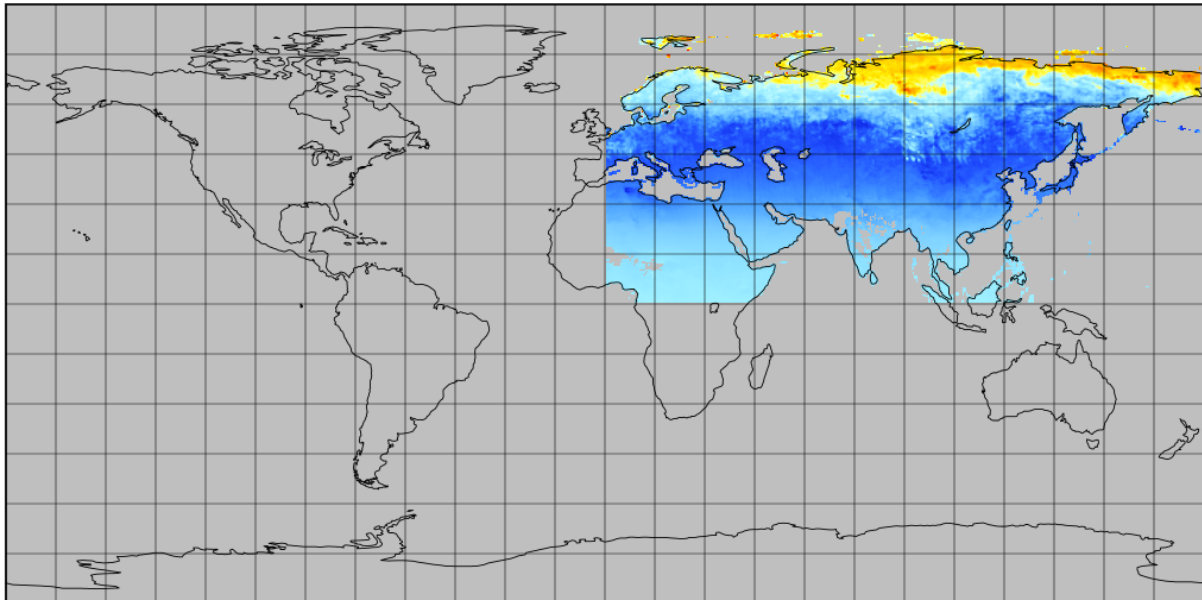


Figure 24: regridded solaz variable

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--	--	---

4.5. Error cases

Some error handling examples:

```
(base) [hillel@ccil dist onefile]$ lst_cci_regrid vl.00 ~/lst_regrid_tool/TDS/ESACCI-LST-L3C-LST-MODISA-0.01deg_1MONTHLY_DAY-20060701000000-fv3.00.nc output_05 --coords "0 100 0 180" --resolution 0.5
Charset normalizer/assets/ init _py17: UserWarning: Charset-Normalizer require /home/users/hillel/conda/env/conda_topack/dist vl.0/lst_cci_regrid vl.00/charset_normalizer/assets/frequencies.json to be existent for language/co
herence detection. Detection will be weaker.
2022-09-26 13:09:34.413 INFO log file: /home/users/hillel/conda/env/conda_topack/dist vl.0/lst_cci_regrid vl.00/lst_cci_regrid ESACCI-LST-L3C-LST-MODISA-0.01deg_1MONTHLY_DAY-20060701000000-fv3.00.nc to 0.5.log
2022-09-26 13:09:34.425 ERROR - latitude 100.0 is outside [-90; 90] boundaries
2022-09-26 13:09:34.435 ERROR - Error occurred parsing arguments: wrong argument list
```

Figure 25: lat / lon out of bound

```
(base) [hillel@ccil dist onefile]$ lst_cci_regrid vl.00 ~/lst_regrid_tool/TDS/ESACCI-LST-L3C-LST-MODISA-0.01deg_1MONTHLY_DAY-20060701000000-fv3.00.nc output_05 --coords "60 50 0 180" --resolution 0.5
Charset normalizer/assets/ init _py17: UserWarning: Charset-Normalizer require /home/users/hillel/conda/env/conda_topack/dist vl.0/lst_cci_regrid vl.00/charset_normalizer/assets/frequencies.json to be existent for language/co
herence detection. Detection will be weaker.
2022-09-26 13:18:25.947 INFO log file: /home/users/hillel/conda/env/conda_topack/dist vl.0/lst_cci_regrid vl.00/lst_cci_regrid ESACCI-LST-L3C-LST-MODISA-0.01deg_1MONTHLY_DAY-20060701000000-fv3.00.nc to 0.5.log
2022-09-26 13:18:25.985 ERROR - latmin 00.0 is greater than latmax 50.0
2022-09-26 13:18:25.985 ERROR - Error occurred parsing arguments: wrong argument list
```

Figure 26: lat/lon wrongly ordered

```
(base) [hillel@ccil dist onefile]$ lst_cci_regrid vl.00 ~/lst_regrid_tool/TDS/ESACCI-LST-L3C-LST-MODISA-0.25deg_1MONTHLY_DAY-20060701000000-fv3.00.nc output_05 --coords "-4 3.75 -32.5 -32.25" --resolution 0.5
Charset normalizer/assets/ init _py17: UserWarning: Charset-Normalizer require /home/users/hillel/conda/env/conda_topack/dist vl.0/lst_cci_regrid vl.00/charset_normalizer/assets/frequencies.json to be existent for language/co
herence detection. Detection will be weaker.
2022-09-26 13:11:31.124 INFO log file: /home/users/hillel/conda/env/conda_topack/dist vl.0/lst_cci_regrid vl.00/lst_cci_regrid ESACCI-LST-L3C-LST-MODISA-0.25deg_1MONTHLY_DAY-20060701000000-fv3.00.nc to 0.5.log
2022-09-26 13:11:31.186 INFO spatial resolution used is geospatial lat_resolution
2022-09-26 13:11:31.204 INFO Open 0.05 degree resolution land mask
2022-09-26 13:11:31.215 INFO use a sub selection of land map
2022-09-26 13:11:31.218 INFO regrid land map to 0.25
2022-09-26 13:11:31.222 INFO Use 8 parallel CPU threads
2022-09-26 13:11:31.223 WARNING Output file output_05/ESACCI-LST-L3C-LST-MODISA-0.5deg_1MONTHLY_DAY-20060701000000-fv3.00.nc exists and will be replaced.
2022-09-26 13:11:31.225 INFO Input file resolution: 0.25
2022-09-26 13:11:31.225 INFO Output file resolution: 0.5
2022-09-26 13:11:31.225 INFO Sub grid coordinates: [-4 3.75 -32.5 -32.25]
2022-09-26 13:11:31.225 INFO -----
2022-09-26 13:11:31.409 INFO REGRID 'dtime' Method mean
2022-09-26 13:11:31.410 ERROR - Invalid --resolution option value. Try a different resolution
Traceback (most recent call last):
  File "lst_cci_regrid.py", line 482, in lst_cci_regrid_var
  File "xarray/core/rolling.py", line 939, in wrapped func
  File "xarray/core/variable.py", line 2194, in coarsen
  File "xarray/core/variable.py", line 2230, in coarsen.reshape
ValueError: Could not coarsen a dimension of size 31 with window 2 and boundary='exact'. Try a different 'boundary' option.
2022-09-26 13:11:31.412 ERROR - Exception occurred during regriding:
```

Figure 27: wrong resolution

NB: resolution value is not fully checked before the regridding starts. Resolution errors are raised at execution time.

5. Performances

The re-gridding tool is a python script supporting multi-threading.

Performances depends on host capabilities, the input file size, the claimed resolution, and the sub-map size.

Tests done on: Intel(R) Core(TM) i7-4770S CPU @ 3.10GHz with 28 GB of RAM

latmin=0 latmax=50 lonmin=0 lonmax=50 Threads=1

Compression Level	0,01° to 0,01° Duration (s)	0,01° to 0,01° Size (MB)	0,01° to 0,05° Duration (s)	0,01° to 0,05° Size (MB)
1	26,44	273	21,73	13
4	30,07	263	21,06	12
9	188,04	256	26,32	12
RAM (MB)	800		550	

latmin=0 latmax=50 lonmin=0 lonmax=50 Thread=2

Compression Level	0,01° to 0,01° Duration (s)	0,01° to 0,01° Size (MB)	0,01° to 0,05° Duration (s)	0,01° to 0,05° Size (MB)
1	20,91	273	13,24	13
4	27,05	263	13,72	12
9	184,83	256	18,48	12
RAM (MB)	820		590	

latmin=-90 latmax=90 lonmin=-180 lonmax=180 Threads=1

Compression Level	0,01° to 0,01° Duration (m)	0,01° to 0,01° Size (MB)	0,01° to 0,05° Duration (m)	0,01° to 0,05° Size (MB)
1	6,72	2279	7,95	102
4	7,53	2164	7,88	97
9	26,7	2111	8,67	95
RAM (GB)	15		6,7	

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